MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

ETN2126 – INFORMATION THEORY AND ERROR CODING

(TE)

5 MARCH 2020
9:00 a.m. – 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with **FOUR** (4) Questions only.

2. Attempt ALL **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Briefly explain the following theorems introduced by Shannon.

(i) Source coding theorem

[2 marks]

(ii) Channel coding theorem

[2 marks]

(iii) Information capacity theorem

[2 marks]

(b) Given a discrete memoryless source (DMS) of alphabet, S = $\{a_0, a_1, a_2\}$ with its symbols having corresponding probabilities of {0.2, 0.3, 0.5}, respectively.

(i) Calculate the entropy for the extended DMS source, $H(S^2)$.

[5 marks]

(ii) Explain the situation for alphabet S where H(S) is maximum. Find the maximum value of H(S).

[5 marks]

(c) Figure Q1 illustrates the channel matrix of a discrete memoryless channel with inputs, $A_X = \{x_0, x_1, x_2\}$ and outputs, $A_Y = \{y_0, y_1, y_2\}$. Let $\{x_0, x_1, x_2\}$ have probabilities of {0.3, 0.3, 0.4}, respectively.

(i) Draw the corresponding discrete memoryless channel.

[4 marks]

(ii) Find the conditional entropy, $H(A_Y|A_X)$.

[5 marks]

$$p(y_k|x_j) = \begin{bmatrix} 0.3 & 0.7 & 0 \\ 0.4 & 0 & 0.6 \\ 0 & 0.2 & 0.8 \end{bmatrix}$$

Channel matrix

Figure Q1

Continue.....

Question 2

(a) Given a discrete memoryless source (DMS) with symbols $\{s_0, s_1, s_2, s_3, s_4\}$ and corresponding probabilities {0.4, 0.2, 0.2, 0.1, 0.1}. Huffman coding is used as the source encoder to encode this DMS.

(i) Briefly explain the basic idea behind Huffman coding.

[2 marks]

(ii) Find the Huffman code for the above DMS such that the variance of the codeword length is small.

[9 marks]

(iii) Compute the efficiency of this Huffman code.

[3 marks]

(iv) State two drawbacks of Huffman coding.

[2 marks]

(b) The basic idea of Lempel-Ziv coding is to construct a codebook from the source data stream itself. Consider the following source data stream:

$$\alpha\alpha\alpha\beta\alpha\beta\beta\alpha\alpha\beta\beta\beta\alpha\beta\alpha\alpha\beta\alpha\beta\beta\ldots$$

Assuming that $\alpha = 1$ and $\beta = 0$, use the Lempel-Ziv algorithm to encode this sequence.

[9 marks]

Continue.....

Question 3

(a) In modern telecommunication systems, error control coding is commonly applied to the information bits before they are transmitted across the channel.

(i) Briefly explain why error control coding is important.

[2 marks]

(ii) Channel encoding is the part that implements error control coding. Briefly explain the working principles of channel encoding.

[3 marks]

(iii) Briefly elaborate on the trade-off that is to be considered in error control coding implementation.

[2 marks]

(b) Linear block codes are a type of error control coding.

(i) State the closure property of linear block codes.

[2 marks]

(ii) Consider a (7, 4) linear block code whose generator matrix is given below.

$$\mathbf{G} = \begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Find all the codewords for this code. Additionally, find the minimum distance for this code.

[6 marks]

(c) Cyclic codes form a subclass of linear block codes.

(i) A binary code is said to be a cyclic code if it exhibits two fundamental properties. State and explain the two fundamental properties.

[2 marks]

(ii) The generator polynomial of a (7, 4) cyclic code is $g(D) = 1 + D + D^3$. Find all the valid codewords of this code in systematic form.

[8 marks]

Continue.....

Question 4

(a) A convolutional encoder has a 2-stage shift register (constraint length, $K = 3$), three modulo-2 adders and an output multiplexer. The generator sequences of the encoder are $g^{(1)} = (1,0,1)$, $g^{(2)} = (1,1,0)$ and $g^{(3)} = (1,1,1)$.

(i) What is the main difference between convolutional coding and block coding? Thus, when is convolutional coding preferred?

[3 marks]

(ii) Draw the block diagram of the convolutional encoder described above.

[5 marks]

(b) Consider the convolutional encoder shown in Figure Q4. Construct the state table for this encoder.

[8 marks]

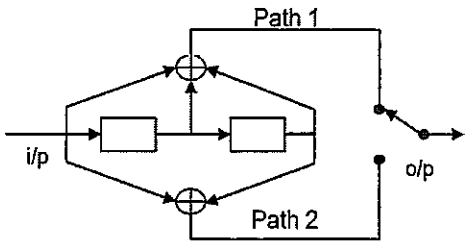

Figure Q4

(c) Trellis coded modulation (TCM) combines convolutional coding with modulation.

(i) Briefly state and explain the key idea that makes TCM successful.

[3 marks]

(ii) Assume that the convolutional encoder of the TCM has k input bits and a rate of $\frac{k}{k+1}$. How many constellation points, M, does the modulation scheme has in this TCM? Draw the functional block diagram of this TCM that includes showing how the convolutional encoder is connected to the modulator.

[6 marks]

End of Paper